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A Bibliometric Analysis of Different Maximum Power Point Tracking Methods for Photovoltaic Systems

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ABSTRACT

The most influential and abundant sources of renewable energy in India is that the solar power. The character of position changing of sun is that the prime obstacle of the appliance of solar power. Due to that, the atmospheric temperature and irradiance intensity are altering through the day. This leads the way towards the variations within the extent of power production. Within the direction of maximization of the facility throughout different times of the day, a way called Maximum point Tracking (MPPT) is employed. The aim of this study is to retrieve the energy from solar by developing an appropriate Maximum Power Pont Tracking technique to style a charge controller.

KEYWORDS: *PV (Photo Voltaic), P & O (Perturb & Observe), InC (Incremental Conductance), ANN (Artificial Neural Network), MPPT (Maximum Power Point Tracking), Particle Swarm Optimization (PSO)*

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INTRODUCTION

The growing energy demand including the likelihood of reduced supply of conventional fuels, evidenced by petroleum crisis, alongside growing concerns about environmental conservation, has driven research and development of other energy sources that are cleaner, are renewable, and produce little environmental impact. Among the choice sources, the electricity from photovoltaic (PV) cells is currently considered a natural energy source that's more useful, since it's free, abundant, clean, and distributed over the Earth and participates as a primary factor of all other processes of energy production on Earth. Moreover, in spite of the phenomena of reflection and absorption of sunlight by the atmosphere, it's estimated that solar power incident on the Earth's surface is on the order of ten thousand-fold greater than the planet energy consumption. An excellent advantage of PV cells is that the reduction of CO2 emissions [1]. By the year 2030, the annual reduction rate of CO2 thanks to the usage of PV cells could also be around 1 Gton/year, which is like India's total emissions in 2004 or the emission of 300 coal plants. Consistent with experts, the energy obtained from PV cells will become the foremost important alternative renewable energy source until 2040 [2]. Tracking the utmost point (MPP) of a photovoltaic (PV) array is typically an important a part of a PV system. As such, many MPP tracking (MPPT) methods are developed and implemented. The methods vary in complexity, sensors required, convergence speed, cost, range of effectiveness, implementation hardware, popularity, and in other respects. they vary from the just about obvious (but not necessarily ineffective) to the foremost creative (not necessarily most effective). In fact, numerous methods are developed that it's become difficult to adequately determine which method, newly proposed or existing, is most appropriate for a given PV system.

Basic model of PV cell

Solar cells are the essential components of PV panels. A photovoltaic cell is essentially a contact which is formed from two different layers of silicon doped with a little amount of impurity [3]. Mostly they're made from Silicon. Solar cells work on the principle of photoelectric effect consistent with which some semiconductors can convert electromagnetic wave directly into electrical current. The charged particles generated by the incident radiation are separated conveniently to make an electrical current by an appropriate design of the structure of the photovoltaic cell [4].

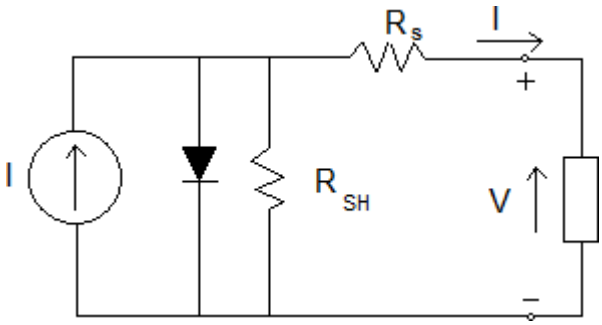

Figure 1: Single diode model of PV cell

In the basic diode model of PV cell, there's a current source (I) alongside a diode and series resistance (Rs). The shunt resistance (RSH) in parallel has very high value and features a negligible effect, hence are often neglected.

The output current from the photovoltaic array is-

$I = Isc - Id$ (1)

$Id = Io\ (e^{qVd/kT} - 1)$ (2)

The final expression of the current after applying approximations to (1) & (2) is:

$I = ISC - I0\ [\exp\{q\ (V+IRS)/nkT\}-1]$ (3)

Where

Io = reverse saturation current of the diode,
Q = electron charge,
V_d = voltage across the diode,
K = Boltzmann constant (1.38 * 10-19 J/K)
T= junction temperature in Kelvin (K)
n = diode ideality factor

The point at which maximum output occurs is obtained by MPPT methods. This is often done by studying the I-V characteristics curve of the cell. When the voltage and therefore the current characteristics are multiplied we get the P-V characteristics as shown in Figure. The purpose indicated as MPP is that the point at which the panel power output is maximum [4].

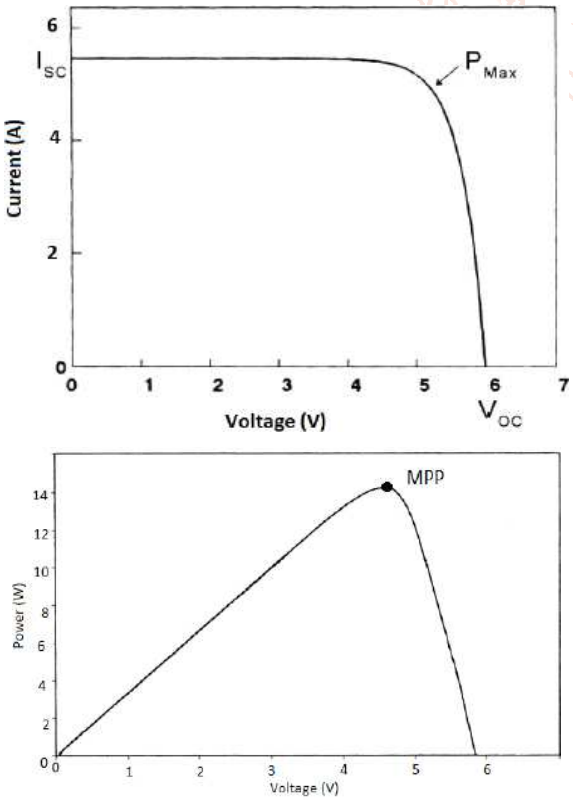

Figure 2: I-V and P-V Characteristics Curve

MPPT Requirement

The power at the output obtained from the solar array is very hooked in to the intensity of obtainable irradiations from sun. The utmost power developed during a solar array system, is essentially rely upon: (i) the load behavior of the entire system, (ii) intensity of sun ray falls on the panel and (iii) atmospheric temperature at that place. The elemental idea of MPPT is that to switch the entire resistance of the circuit seen by the panel in order that it can generate maximum power output. So, to get maximum power the MPPT technique automatically adjusts the load settings of the systems. MPPT is employed for coitus interrupts the utmost power from the solar array and convey that extracted power to the destination load. Dc-dc converter (step up / step down) operates like an interface in between the load and therefore the panel, to serve the intention of transmitting maximum power from the solar array to load [5]. By altering the duty ratio the impedance of load is harmonized with the panel impedance to urge maximum power from the panel. Point of maximum power is tracked with altering the duty ratio of the facility electronics converters to manage the voltage at output. The choice of sort of converter are going to be used for any purpose is directly depends upon the wants of voltage output by the load. Adequate research is on progress during this part to maximize the facility generation efficiency of the solar PV panel. The main aim in MPPT is to regulate the duty ratio (D) of the converter used. within the source side we use a convertor that's connected to a solar array so as to reinforce the output voltage and by changing the duty cycle of the converter appropriately the source impedance are often matched with the load impedance.

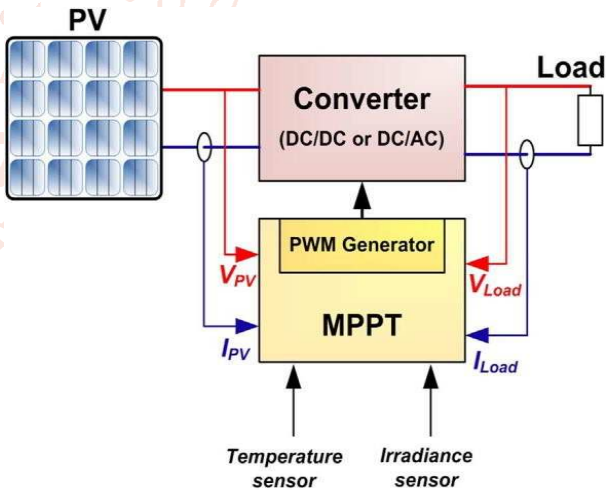

Figure 3: General scheme of a PV with an MPPT system.

DIFFERENT MPPT TECHNIQUES

1. Perturb & Observe

In P and O method, we use just one sensor hence it's easy to implement. Voltage sensor used senses the PV array voltage then the value of implementation is a smaller amount. The time complexity of this algorithm is extremely less but on reaching very on the brink of the MPP it keeps on perturbing on both the directions. But we will set some error limit as perturbations occurs near MPP. But this method doesn't consider change in irradiation level thanks to perturbation and hence calculates the incorrect MPP. To avoid this problem we will use incremental conductance method.

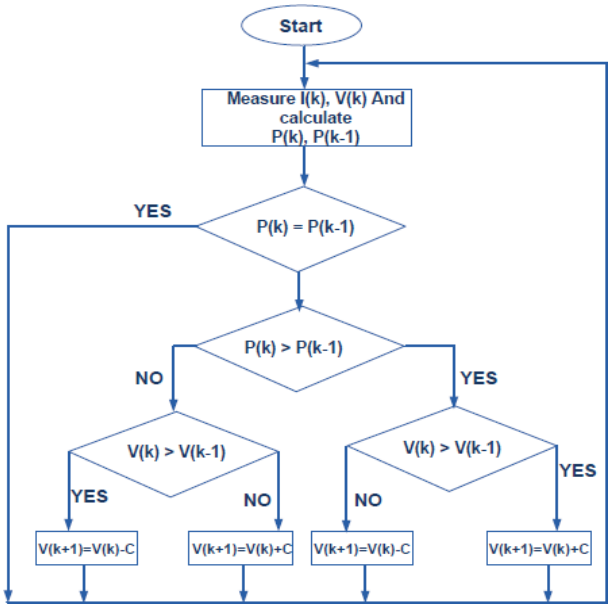

Figure 4: Flowchart of P&O method

2. Incremental Conductance

The disadvantage of the perturb and observe method to trace the height power under fast varying climate is overcome by IC method. The IC can determine that the MPPT has reached the MPP and stop perturbing the operating point. If this condition isn't met, the direction during which the MPPT operating point must be perturbed are often calculated using the connection between dl/dV and –I/V This relationship springs from the very fact that dP/dV is negative when the MPPT is to the proper of the MPP and positive when it's to the left of the MPP. This algorithm has advantages over P&O therein it can determine when the MPPT has reached the MPP, where P&O oscillates round the MPP. Also, incremental conductance can track rapidly increasing and decreasing irradiance conditions with higher accuracy than perturb and observe. One disadvantage of this algorithm is the increased complexity in comparison to P&O.

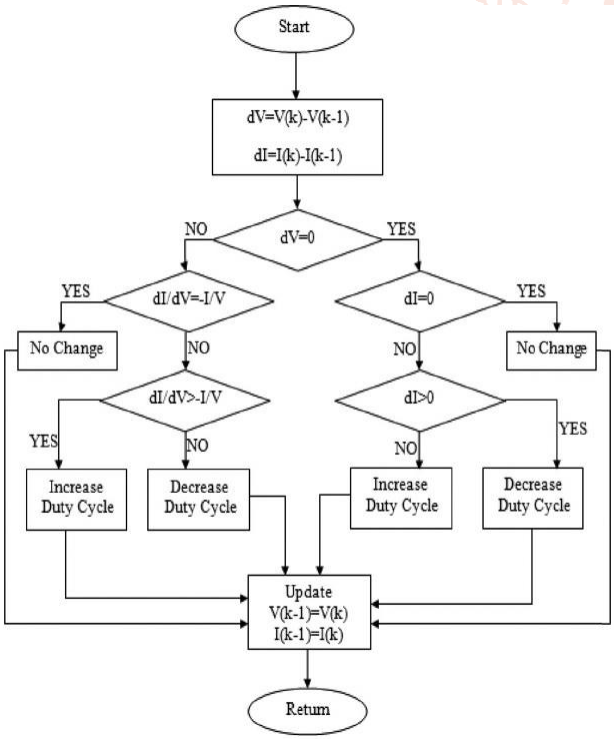

Figure 5: Flowchart for incremental conductance method

3. Fractional Open Circuit Voltage

This method uses the approximately linear relationship between the MPP voltage (VMPP) and therefore the circuit voltage (VOC), which varies with the irradiance and temperature.

$$V_{MPP} \approx k\, V_{OC} \qquad (4)$$

Where, k may be a constant and depends on the array characteristics and it must be determined for various levels of irradiance. It's value varies between 0.71 and 0.78. To live, the system is pack up for brief time which causes momentarily power loss. This analysis gives approximate value of VMPP.

4. Fractional Short Circuit Current

It is same as fraction circuit, but here the connection is between MPP current (IMPP) and short current (ISC) for varying atmospheric conditions.

$$I_{MPP} \approx k' I_{SC} \qquad (5)$$

The coefficient of proportionality k' is obtained consistent with each PV array. It's value varies between 0.78 and 0.92. to live ISC, a further switch to power converter is required to periodically short the PV array.

5. Fuzzy Logic Control

This method can affect imprecise inputs and doesn't need an accurate mathematical model **and may** handle nonlinearity. The symbolic logic control generally use microcontrollers. The symbolic logic works in three stages: i) fuzzification, ii) inference system and iii) defuzzification. Fuzzification is that the process of remodeling crisp inputs into linguistic variables supported the degree of membership to certain sets. Membership functions are **wont to** associate a grade to every linguistic term. The amount of membership functions used depends on the accuracy of the controller, but it always varies between 5 and 7. In second stage rule based table is meant **supported** some rules which associates the fuzzy output to the fuzzy inputs supported the facility converter used and on the knowledge of the user [8]. The last stage of the symbolic logic control is that the defuzzification. Within the defuzzification stage the output is converted from a linguistic variable to crisp **once more** using membership functions.

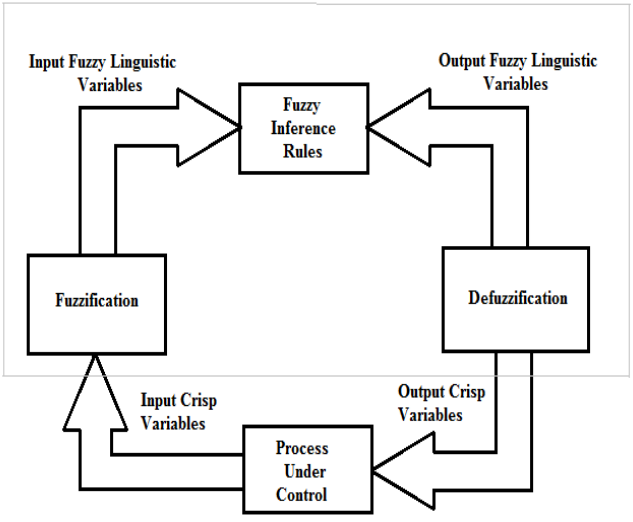

Figure 6: Fuzzy Logic

6. Neural Network

Neural network and fuzzy logic comes under Soft Computing. The logic of neural network is motivated by the subtle functionality of human brain where many billions of interconnected neurons process information in parallel. The only example of a Neural Network has three layers called the input layer, hidden layer and output layer, as shown in Figure

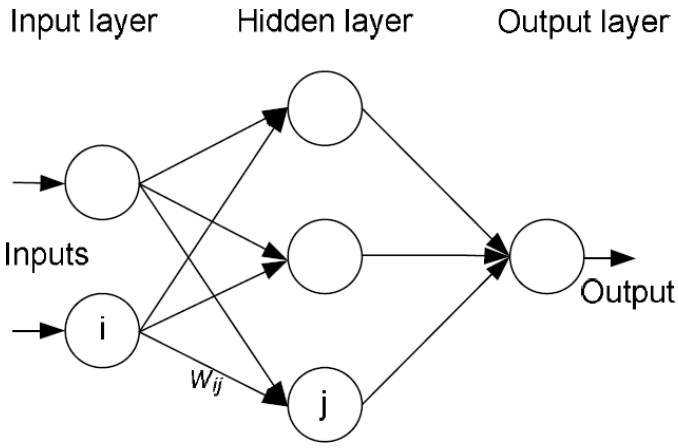

Figure 7: Neural Network

More complicated NN's are often built adding more hidden layers counting on user knowledge. The input variables are often parameters of the PV array like VOC and ISC, atmospheric data as irradiation and temperature or a mixture of those. The output is typically one or more reference signals just like the duty cycle or the DC-link reference voltage [8]. The performance of the NN depends on the functions employed by the hidden layer and the way well the neural network has been trained. In Figure the load between the nodes i and j is labelled as wij. The weights are adjusted within the training process. For this, data is recorded for a period of your time in order that the MPP are often tracked accurately.

The main disadvantage of this MPPT technique is that the info needed for the training process has got to be acquired for each PV array and site. Because the characteristics of the PV array vary counting on the model and therefore the atmospheric conditions depend upon the situation. These characteristics also change with time, therefore the neural network has got to be periodically trained.

7. Particle Swarm Optimization

This technique is one among the highly potential technique among various evolutionary algorithms due to its simple structure, fast computation ability **and straightforward** implementation. PSO is predicated on the behaviour of bird groups and may be a population based stochastic search method. The PSO algorithm maintains a swarm (group) of people (called particles), where each particle represents a candidate solution. Each particle tries to compete with the success of neighbouring particles and its own attained success [4]. Thus the position of every particle depends on the simplest particle **during a** neighborhood (Pb) and on the simplest solution (Gb) establish by all the particles within the complete population.

$$d_i^{k+1} = d_i^k + \emptyset_i^{k+1} \quad (6)$$

Where Øi represents the step size of velocity component.

$\emptyset_i^{k+1}$ is calculated using Eq. (6), where k1 and k2 are the acceleration coefficients, w is the inertia weight,, r1, r2 lies between 0 and 1, Pb is the best position of particle i, and Gbis the best position of the particles in the complete population.

$$\emptyset_i^{k+1} = w\emptyset_i^k + k_1 r_1\{P_{bi} - x_i^k\} + k_2 r_2\{G_b - x_i^k\} \quad (7)$$

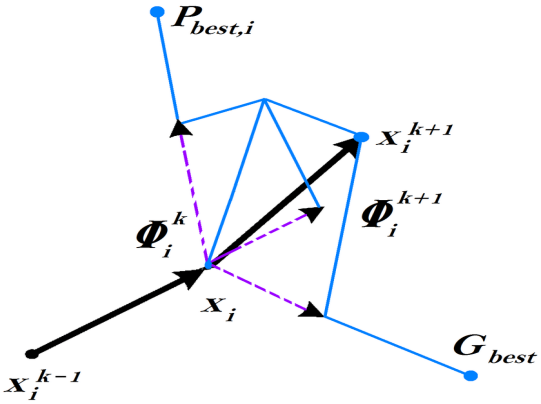

Figure 8: Movement of particles in optimization process

Fig. 8 shows the standard movement of particles within the optimization process. PSO method works efficiently for non- uniform irradiance conditions but the initial position of the particles plays an excellent role within the convergence of this method. It's been observed that when the particles reach the MPP, the speed related to the particles becomes very low or practically zero.

Table 1: Comparison of MPPT techniques according to several parameters

Sr. No.	MPPT technique	Convergence speed	Implement -ation complexity	Periodic tuning	Sensed parameters	Efficiency (%)	Analog or Digital Control	True MPPT	Cost	Control Strategy	Stability
1	Perturb & observe	Varies	Low	No	Voltage, Current	Medium	Both	Yes	Moderate	Sampling	Not Stable
2	Incremental conductance	Varies	Medium	No	Voltage, current	Medium	Digital	Yes	Moderate	Sampling	Stable
3	Fractional V_{OC}	Medium	Low	Yes	Voltage	Low	Both	No	Cheap	Indirect	Not Stable
4	Fractional I_{SC}	Medium	Medium	Yes	Current	Low	Both	No	Cheap	Indirect	Not Stable
5	Fuzzy logic control	Fast	High	No	Varies	Very High	Digital	Yes	Expensive	Probabilistic	Very stable
6	Neural network	Fast	High	No	Varies	Very High	Digital	Yes	Expensive	Probabilistic	Very Stable
7	Particle Swarm Optimization	Fast	Medium	No	Varies	High	Digital	Yes	Expensive	Probabilistic	Very Stable

Conclusion

Currently, the usage of energy from PV panels is a reality, and its intensive use will become extremely important find solutions to energy and environmental problems very soon. During this context, the used MPPT techniques are the foremost important to extract the utmost power available in PV. From a few years researchers and scientists are performing on renewable energy sources. MPPT is that the technique for increasing the output efficiency and mainly used for system and play vital role in electricity generation. During this study, general classification and descriptions of the foremost widely used seven MPPT techniques are analyzed and compared to means the benefits and disadvantages of varied MPPT methods. This paper is useful for choosing a MPPT technique depending upon various constraints as given within the table. In practice, the foremost widely used techniques are P&O and IC thanks to their simple structures and low cost. Recently, the software-based artificial intelligent techniques like FL and ANN are growing in MPTT applications.

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